AC 2007-2202: ASSESSING ACTIVITY SYSTEMS OF DESIGN TEAMS IN A COLLABORATIVE SERVICE LEARNING ENVIRONMENT

Scott Schaffer, Purdue University

Kimfong Lei, Purdue University

Lisette Reyes, Purdue University

William Oakes, Purdue University

Carla Zoltowski, Purdue University

Assessing Activity Systems of Design Teams in a Collaborative Service Learning Environment

Abstract

This study focused on an assessment process and cross-disciplinary team learning framework potentially useful in the design of collaborative environments for project teams. This following research questions addressed were: 1) Did individual self assessment of skills, abilities and attitudes match with perceived team goals; 2) Did teams believe they acquired the resources and support required to transform from individual to group cognition; and 3) What impact did the sociocultural context have on teams' ability to accomplish the previous two components as well as achieve outcomes. Two cross-disciplinary engineering teams in a university service learning program were observed, interviewed, and surveyed while completing projects. A comparative, multi-case study design was employed to study an award-winning, cross-disciplinary team and a more typical team comprised of only engineers. Tensions and contradictions within and across team activity systems were identified and contrasted. The extent to which teams evolved from an emphasis on individual learning toward cross-disciplinary learning during projects was also assessed. Results are discussed in the context of a cross-disciplinary team learning framework that is currently being validated by the research team.

Introduction

Assessment of collaboration patterns and learning among team members engaged in long-term projects such as university service learning projects is complex and requires a multi-faceted approach. Teams members interact and collaborate with clients, advisors, and peers on complex, time sensitive projects. A combination of theoretical frameworks is necessary to begin to understand the evolution of individual to group to team cognition and learning within various contexts. A combined framework termed the cross-disciplinary team learning (CDTL) framework is currently being validated by the research team[1]. A validated CDTL framework along with several documented cases of team collaboration describing the complexity of team learning provides excellent grounding for the design of team collaboration software.

Two theoretical frameworks supported the assessment of context and cross-disciplinary team learning in this study. The first is activity theory (AT), which is a multi-disciplinary theory for studying human activity from a cultural-historical perspective with roots in the works of Vygotsky[2] and Leont'ev[3]. Engeström[4] further modified activity theory and included several socio-cultural elements. According to Bannon[5], AT is not a "theory" in a strict interpretation of the term but a set of principles devised to explain a group of phenomena, especially one that has been repeatedly tested and can be used to make predictions about natural phenomena. Representations of team activity systems derived from the theory were utilized to understand the holistic nature and structure of team collaboration including the mediating effect of tools, roles, communities, rules, and division of labor on the transformation of objects into outcomes[4, 6, 7]. There are several examples of activity systems representations within business-industry settings[8, 9, 10, 11, 12], and particularly as such systems pertain to the use of computer supported collaborative learning in complex work environments[13, 14, 15, 16]. The complex social climate of the workplace, i.e. the community, the rules, and the division of labor, must be understood to realize the full potential of computer supported collaboration tools.. For example, it is difficult to provide peer feedback and reflect on team learning processes when deadlines are looming. Strategies are required to support integration of individual and team shared mental models.

A second perspective that influenced the design of this study is Fruchter & Emery's[17] cross-disciplinary learning (CDL) model. The CDL model, based on Fruchter & Emery's work with architecture, engineering, and construction (AEC) student teams, provides insight into the process of assessing how cross-disciplinary teams communicate and integrate the concepts, models, and discipline-specific language used by one another. They identified four dimensions of CDL that teams are believed to evolve through during a project. The dimensions are described in the following way: 1) Islands of knowledge; the student has mastered his or her discipline but has little experience in other disciplines. 2) Awareness; the student is aware of other discipline's goals and constraints. 3) Appreciation; the student begins to build a conceptual framework of the other disciplines, and understand enough about them to ask good questions. 4) Understanding; the student develops a conceptual understanding of the other disciplines, can negotiate, is proactive in discussions with participants from other disciplines, provides input when requested, and begins to use the language of the other discipline. While the CDL model is one way to represent the progression of cross-disciplinary learning through team participation, other studies related to cross-disciplinary learning in teams have been done in the area of urban planning, as well as within the instructional and multimedia design fields[18, 19].

An extension and adaptation of the CDL model developed by Schaffer & Lei termed the cross-disciplinary team learning (CDTL) framework was used as the basis for interpreting individual to team learning patterns in this study. The framework incorporated three major processes: identification, formation, and adaptation that incorporate fundamental team activities as defined by Ilgen, et. al.,[20] in a recent meta-analysis of team studies. In the CDTL framework, individuals are believed to evolve through specific self-assessment and reflective processes early in their project experience, in an effort to identify the degree to which they fit with the team vision and goals. Identification of one's own beliefs about being a successful team member as well as establishment of initial team bonds was prominent. As goals are clarified and team leaders emerge, teams begin to form rules, divide labor, and establish lines of communication. Formation is thus a critical linking process that helps to create a team culture through management of operations and strategies that maintain feedback and reflection processes. Adaptation is a collective process whereby teams think deeply about design alternatives collectively, in a team structure that requires openness to other disciplines and awareness, appreciation, and understanding of the language, techniques, and processes unique to those disciplines. Very few teams appear to truly go beyond formation to the adaptation process in part because so few projects demand innovation which requires problem finding and expanding conceptions of what solutions can be.

Data Collection

Several data collection approaches were employed to learn about teams including questionnaires, interviews, and focus groups. First, a comparative, multiple case study design was used to select 2 teams from 35 teams in a university community engagement program. This program is designed to give teams of undergraduate students with active learning experiences within real world contexts. Student teams work with advisors and clients to define project scope, create alternative designs, and develop, test, and implement solutions. The multiple cases were analyzed for the purpose of theoretical replication, which either (a) predicts similar results or (b) produces contrasting results but for predictable reasons. The development of a rich, theoretical framework is an important step in all of these replication procedures[21]. Multiple cases were compared with the elements of activity theory. In-depth observations and interviews were conducted with two teams. Observations consisted of recording the peer interaction process of a team while they were engaged in problem-solving tasks. Follow-up video-taped interviews were conducted with these teams toward the end of the semester. In both observations and interviews, a data capture tool based on activity systems was used to facilitate efficient and accurate recording and coding. Teams were also asked to collaborate on a single team response to questionnaire items focused on team performance on project outputs, as well as the degree to which they believed they learned about one another's discipline on the project.

Findings

The two teams that were assessed for this study were quite different in terms of composition, task demands, and general approach to working together. The Mars Rover team served as the exemplar since it was comprised of students from different engineering sub-disciplines (electrical, computer, mechanical) and computer graphics technology and it received a national award for the excellence of its design product at the end of the semester. The Mars Rover team designed and constructed an exhibit for a local science museum that focused on space travel. The Traffic team designed three different solutions on traffic problems for schools within a local school district. Team compositions are shown in Table 1.

Table 1: Composition of teams

	Mars Rover	**Traffic**
Student Majors	Computer (2), Electrical (3), and Mechanical (2) Engineering, Computer Graphics Technology (1)	Electrical (5), Mechanical (1), and Civil Engineering (1)
Academic levels	2 sophomores, and 2 juniors, 4 seniors,	1 sophomore and 2 juniors, 4 seniors,
Gender	1 females, 7 males	3 females, 4 males
Ethnicity	7 Caucasians, 1 Asian	2 Caucasians, 5 Asians
Total team members	8	7

Activity systems diagrams for each team are shown in figures 1 and 2. These are quite high level system descriptions that are meant to provide a global view of the respective team contexts. Primary and secondary tensions and contradictions within and across teams are shown in Table 2. Brief descriptions of each activity system element are also provided which provide a bit more information about each team and to compare and contrast the collective team dynamics and support structures. Furthermore, team cross-disciplinary learning data suggested that teams differed in key ways with respect to the degree to which they learned from one another's disciplines during projects. Space limitations have permitted only brief descriptions of this data but this data is reported in more detail in Schaffer, Lei, and Reyes[22].

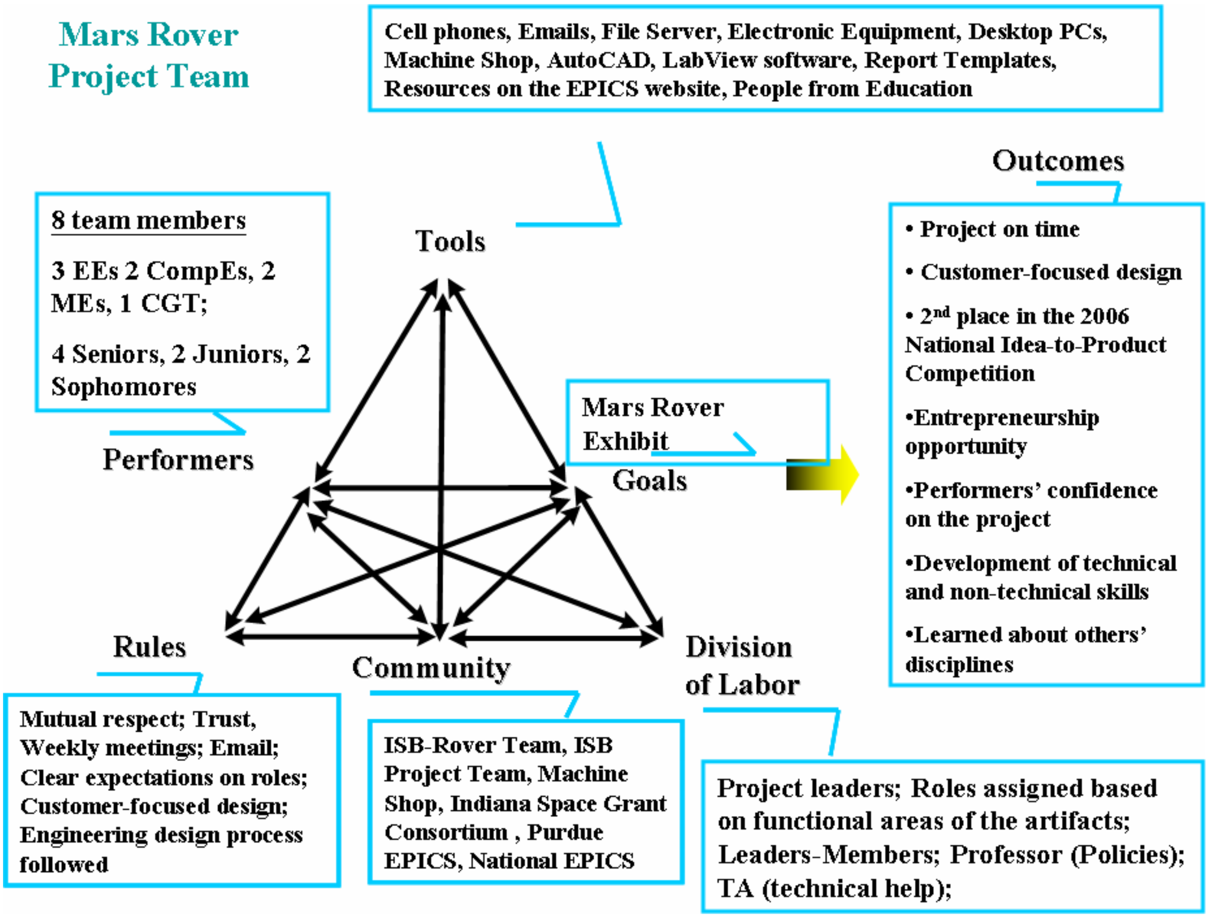


Figure 1. Activity system of the Mars Rover team

Mars Rover Team

Performers and Goals: The Mars Rover project team worked with a local science museum to design the Mars Rover exhibit. The team was composed of different engineering and technology majors, and different class levels. The overall project goal of the Mars Rover project was to create a science exhibit that simulated the behavior of a Mars Rover mission both on Mars and on Earth. The simulated rover science missions were aligned with NASA's four main Mars exploration goals. The rover was equipped and piloted using an instrumentation arm control and camera. Science information would be presented to the user in the form of text, narrations, photographs, and video through a graphical interface on a computer LCD screen. The ISB-Rover exhibit was designed to be enjoyed by a wide range of age groups, however, the educational goals for the prototype exhibit were geared to meet the needs of national and state academic standards for the 5th and 6th grade.

Outcome: The project was on time and a customer-focused design. The team won the 2nd place in the 2006 National Idea-to-Product competition and was asked to produce similar exhibits for different organizations. Students all felt confident on the project at the end. New team members said they could continue on the project. Team members indicated they gained technical and non-technical skills, such as teamwork, communication, and etc. Furthermore, they expressed that they learned about others' disciplines by sharing one another's work, and by cross-teaching one another during the meetings.

Tools: The team mostly used phones and email to communicate. Overall the team used different engineering equipment and components as necessary. The mechanical engineers relied on the Machine Shop in the Mechanical Engineering department to building hardware. Computer Graphics were done with AutoCAD. The team liked their work environment, especially the off-campus laboratory which provided spacious workspace and storage for product development. The team also valued people from the College of Education as resources to help them identify the educational standards and needs of 5-6th graders.

Community: The Mar Rover team and other sub-teams worked with a variety of stakeholders including the science museum client, university service learning program advisors and teaching assistants, as well as resources in the program. The teams reached out to build communities to expand their project. For instance, The Mar Rover team also had excellent working relationships with people in the University Machine shop. The team also had regular communications with the Indiana Space Grant Consortium and its director.

Division of Labor: The team broke down tasks according to functionalities of the exhibits and assigned roles such as Project Leader, Team Leader, Graphic Designer, Landscape Planner, Positioning System, Rover Body Design and Construction, Gear Train System, Educational Materials. Team leaders were instrumental in helping new team members get into the flow of the project and had to determine when they needed to share responsibility. The leaders also believed that team members had mutual trust between one another. Professors helped with program processes and policies. The teaching assistant helped with the use of software and technical problems, clarifications of policies and requirements.

Rules: The team indicated they had mutual respect for everyone. Team members shared the work load as needed. They were aware of the limitation of each individual, e.g. "I can't do this myself/can't do it all". Weekly meetings were hold outside the lab time to report individuals' status and receive peer feedback. Communications were done mostly via emails. The team indicated that it was important to focus on a customer's needs as they were trying to balance educational goals and technical goals. Overall, the team followed a general engineering design process.

Cross-disciplinary learning: The Mars Rover team members appeared to assign team roles and tasks, i.e. division of labor, according to specific team member skills. They reported higher levels of perceived innovation, creativity, goal clarity, feedback from advisors, and sharing of theories and processes than the Traffic Team.

Traffic Team

Performers and Goals: The project team was composed different engineering majors in different class levels. Furthermore, six of the eight members were new to service learning program, and indicated they lacked of the confidence to work on this project. Only a few indicated they had enough confidence to contribute to the projects with their knowledge and skills in their disciplines. The team worked for the local school corporation to eliminate traffic congestion as well as solve various traffic issues that would occur over and around the campus areas. The team considered the use of automated solutions designed and customized specifically for each problem in each school such as an automated sensor driven gate. During the Spring 2006, the major goal of the team was to design a plan for a prototype which was due in Fall 2006. They believed they chose the best options out of several alternatives. However, they did not have evaluation plans yet because they argued that they did not have anything to test.

Outcome: Team members indicated that they increased their level of professional skills such as project management, interaction with partners, problem solving, technical skills in each disciplines, and teamwork. They also valued the experience and felt they could share the experience with potential employers during interviews.

Tools: The team usually used cellphones, email and instant messengers, such as MSN and AOL, to communicate. They used equipment such as camera, video cameras, and electrical components as needed. The team did not use the service learning program's class management system (i.e. WebCT) although it was available. The team relied on Internet search engines, i.e. Google, to search similar projects, specifications of devices, and other information relevant to the projects. We valued the advices from professors in the service learning program, as well as those in electrical, civil, and mechanical engineer departments.

Community: The Traffic team formed three small sub-project teams on small projects. Members participated across sub-projects based on the needs for different expertise. The primary local community was the overall Traffic team. Similar to the Mars Rover team, the team was situated in the service learning program and accessed to available resources. The team reached out to seek help from other entities within the university, for example, professors in various engineering departments. Therefore, the only connection outside the university context was the local school corporation.

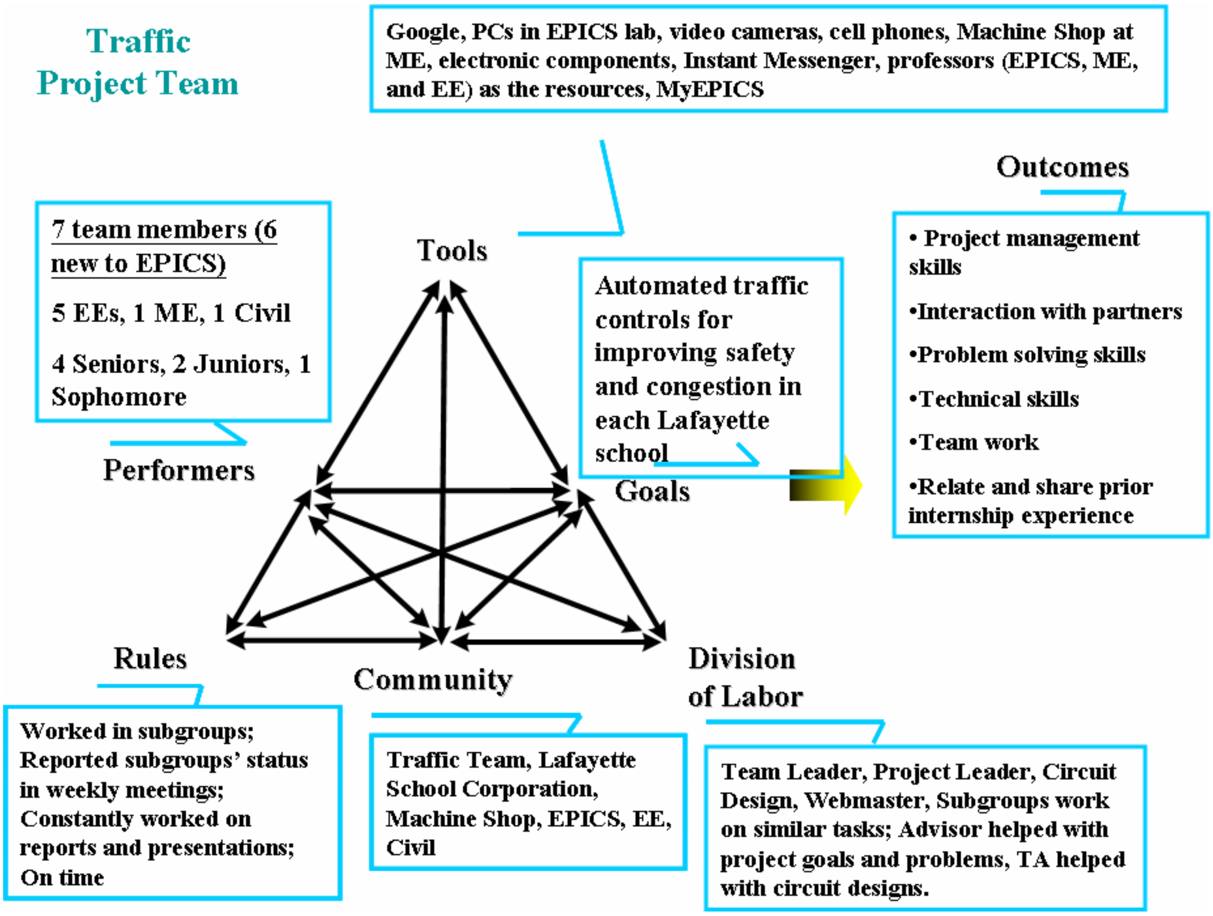


Figure 2. Activity system of the Traffic team

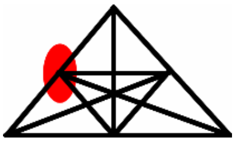
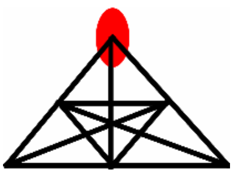
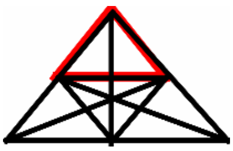
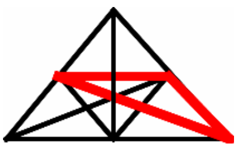
Division of Labor: The team members broken down the granularity of tasks and assigned responsibilities to members based on disciplines. The leaders in the teams were sophomore and expressed lack of experience and confidence of managing the projects. One of the leaders expressed the need for taking more classes within one's discipline. Three sub-teams worked on similar tasks but all team members met altogether to report project status.

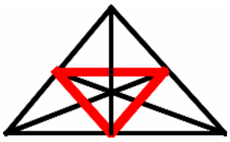
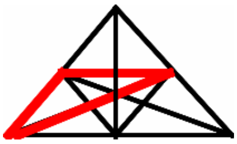
The team indicated they relied on the advices from the advisor and the client. Although they made changes, the final decisions were made based on the recommendations from the advisor or the client. The team indicated that the client wanted the team to do whatever the partner asked them to do. Team members greatly valued the help of teaching assistants on circuit design.

Rules: Sub-teams worked on three projects and had weekly status update meetings. They were concerned that they had to constantly work on reports and presentations.

Cross-disciplinary learning: The Traffic team reported that they felt they worked collaboratively at all times and shared all decisions. They were, however, quite inexperienced, less confident in their technical skills and knowledge levels, and had difficulty managing processes as efficiently as Mars Rover. In effect, they cooperated and communicated well but had fundamental individual flaws that limited any attempts at real collaboration.

Table 2: Contradictions in Activity Systems

Element/ Sub-Activity Triangle	**Area of Contradictions**	**Culture Themes (Mars Rover vs. Traffic)**
Performers 	Experience Confidence Leadership	Expert vs. novice. Increased vs. lack of confidence. Developed vs. developing leadership.
Tools 	Communication and collaboration tools Technical tools	Competing technologies within and outside the context, e.g. instant messengers, Blog, etc.vs. WebCT. Project specific tools vs. general tools.
Performers-Tools-Goals 	Performance support materials Resources and expertise	Support materials guiding problem-solving vs. lack of support materials. Proactively seeking external resources vs. reactively seeking internal assistance
Performers-Division of Labor-Goals 	Team interaction Leadership Relationships with advisors/experts	Collaboration vs. tasking; Multi-ethnic vs. single-ethnic. Team leader proactively involved vs. reactive leadership. Advisors/experts as facilitators vs. leaders.

Element/ Sub-Activity Triangle	Area of Contradictions	Culture Themes (Mars Rover vs. Traffic)
Performers-Community-Artifacts 	Team community External community	Social dimension version vs. task. Multi-cultural vs. Not multi-cultural. Continuously develop strategic partnerships with other communities vs. maintain current partnerships.
Performers-Rules-Artifacts 	Trust Feedback Rewards & incentives	Trust building vs. rule driven. Clear roles and frequent feedback. Exceeding vs. meeting customer' expectation.

Conclusions

Three essential components of team work and learning explored in this study include: 1) individual self assessment of the fit of their skills, abilities and attitudes with perceived team goals; 2) team assessment of the degree to which they are acquiring resources, support, and transforming their thinking processes from individual to group; and 3) the social and cultural context in which team members attempt to accomplish the previous two components as well as achieve outcomes. The current cases provide a glimpse into the opportunities afforded designers of software for such teams through the use of multi-faceted assessment approaches. There is considerable opportunity for researchers to develop frameworks to guide studies of teams in context. The Mars Rover and the Traffic teams in this study were both comprised of a group of hard working individuals. Only one group emerged with characteristics that suggested that individuals learned from one another. This may have only been possible given particular activity system tensions and contradictions. Systematic study of the relationships between a group's systems: activity, performance support, and learning support, may help understand the conditions that foster successful team formation. The degree to which a computer supported collaborative learning environment can effectively help to create such conditions within working teams appears to be fertile ground for future research.

References

1. Schaffer, S.P. and K. Lei, *Cross-disciplinary team learning: Model and scale development.* in press.

2. Vygotsky, L.S., *Mind in society: The development of higher psychological processes*. 1978, Cambridge, MA: Harvard University Press.

3. Leont'ev, A.N., *Activity, consciousness, and personality*. 1978, Englewood Cliffs, NJ: Prentice-Hall, Inc.

4. Engeström, Y., *Learning by expanding: An activity-theoretical approach to developmental research*. 1987, Hlesinki: Orienta-Konsultit.

5. Bannon, L.J., *Activity theory*. 1997.

6. Jonassen, D.H. and L. Rohrer-Murphy, *Activity theory as a framework for designing constructivist learning environments.* Educational Technology Research and Development, 1999. 47(4): p. 61-79.

7. Barab, S.A., M.A. Evans, and E.-O. Baek, *Activity theory as a lens for charactering the participatory unit*, in *International Handbook on Communication Technologies*, D.H. Jonassen, Editor. 2003, Erlbaum: Mahwah, NJ. p. 199-214.

8. Engeström, Y., *Expansive learning at work: Toward an activity theoretical reconceptualization.* Journal of Education and Work, 2001. 14(1): p. 133-156.

9. Hara, N. and T.M. Schwen, *Communities of practice in workplaces: Learning as a naturally occurring event.* Performance Improvement Quarterly, 2006. 19(2).

10. Ho, L.-A. and T.M. Schwen, *Evaluation of the design of complex systems.* Performance Improvement Quarterly, 2006. 19(2).

11. Kaptelinin, V., B.A. Nardi, and C. Macaulay, *Methods & tools: The activity checklist: A tool for representing the "space" of context.* Interactions, 1999. 6(4): p. 27-39.

12. Marken, J.A., *An application of activity theory: A case of global training.* Performance Improvement Quarterly, 2006. 19(2).

13. Collis, B. and A. Margaryan, *Appling activity theory to computer-supported collaborative learning and work-based activities in corporate settings.* Educational Technology Research and Development, 2004. 52(4): p. 38-52.

14. Engeström, Y., *Activity theory and individual and social transformation*, in *Perspectives on Activity Theory*, Y. Engestrom, R. Miettinen, and R.-L. Punamaki, Editors. 1999, Cambridge University Press: New York, NY. p. 19-38.

15. Holland, D. and J.R. Reeves, *Activity theory and the view from somewhere: Team perspectives on the intellectual work of programming*, in *Context and consciousness: Activity theory and human-computer interaction*, B.A. Nardi, Editor. 1996, The MIT Press: Cambridge, MA.

16. Tzeng, J.-Y., *Developing and sharing team mental models in a profession-driven and value-laden organization: A case study.* Performance Improvement Quarterly, 2006. 19(2).

17. Fruchter, R. and K. Emery, *Teamwork: Assessing cross-disciplinary learning*, in *Proceedings of the Computer Support for Collaborative Learning (CSCL) 1999 Conference*, C. Hoadley and J. Roschelle, Editors. 1999: Stanford University, Palo Alto, California.

18. Arias, E.G., H. Eden, and G. Fisher, *Enhancing communication, facilitating shared understanding, and creating better artifacts by integrating physical and computational media for design*, in *Proceedings of*

the conference on Designing interactive systems: processes, practices, methods, and techniques, S. Coles, Editor. 1997, ACM Press: New York. p. 1-12.

19. Schaffer, S.P., M.L. Price, and A. Lapham, *Cross disciplinary, cross cultural community building*, in *Interactive convergence: Interdisciplinary research in multimedia*, M.L. Price and S.P. Schaffer, Editors. 2005, Rodopi Press: Amsterdam.
20. Ilgen, D.R., et al., *Teams in organizations: From input-process-output models to IMOI models.* Annual Review of Psychology, 2005. 56: p. 517-543.
21. Yin, R.K., *Case study research: design and methods*. 2 ed. 1994, Thousand Oaks, CA: Sage.
22. Schaffer, S.P., K. Lei, and L. Reyes, *Assessing cross-disciplinary service learning team.* in press.